RECLAMATION
Managing Water in the West

BF Sisk – Geologic and Geotechnical Investigations

During the most recent dam-safety review of B.F. Sisk Dam, the Bureau of Reclamation, in consultation with the California Department of Water Resources (DWR), determined that concerns about the seismic safety of B.F. Sisk dam provide sufficient justification for corrective actions to improve the safety of the dam. This decision is a result of the following developments:

- Increases in the estimates of both the severity of ground shaking due to nearby earthquake faults, primarily the Ortigalita fault, which crosses San Luis Reservoir, and the probability of a large event on the Ortigalita fault.
- New understanding of the properties of the dam's foundation materials and their ability to resist deformation when subjected to severe shaking.
- Advances in computer-based analysis methods, which allow better assessment of the behavior of the dam under seismic loading.

1. When the dam was constructed in the mid 1960s, it was recognized that the site could be subjected to earthquake shaking. At that time, the greatest concern was a large earthquake emanating from the San Andreas Fault. Although geologic investigations for the design and construction of the dam identified several faults in and near the reservoir, they were not considered potential sources of strong shaking under the criteria that existed at that time.

2. The late 1970s brought a new level of national concern for dam safety, and in the early 1980s, additional seismic hazard investigations were performed for B.F. Sisk and other dams nearby. These investigations concentrated on the age and extent of the Ortigalita fault, and estimated that it had the potential to produce an earthquake of about magnitude 6.75.

3. During the early 2000s, additional seismologic investigations determined that the section of the Ortigalita fault closest to B.F. Sisk Dam was longer than previously thought. (The length of a fault is a rough indication of potential earthquake magnitude.) In addition, the estimated time between large earthquakes on the fault was determined to be somewhat shorter than previously thought, although an earthquake in any given year is still considered a fairly remote possibility. Engineering analyses were also performed at this time, to predict the behavior of the dam under the severe earthquake loading now considered possible.

4. B.F. Sisk Dam was constructed on a series of hills, with the central portion of the dam crossing the valley that contains San Luis Creek. The portions of the dam that bear on the hills, including each end of the dam, are referred to as the abutment sections of the dam. Before the dam embankment was constructed in those areas, a "cutoff trench" was excavated to bedrock on the upstream side of the foundation, and was then backfilled with compacted clayey earthfill to control seepage through the foundation soils. The rest of the abutment surfaces were stripped of

the soft upper layers to reach material that was hard and difficult to remove, which was expected to be stronger than the embankment fill. However, the judgment of strength was made based on the *dry* material exposed in the excavation, and the effects of wetting were not fully accounted for. Once wetted, this material can be weaker than the embankment, and the embankment could slide on it under strong earthquake loading; this could allow some settlement or slumping of the embankment. The settlement could encroach significantly on the freeboard (the height of the embankment above the reservoir surface), but the embankment is expected to be stable in its deformed condition at the end of the earthquake, and not to deform except during the strongest pulses of the earthquake.

5. The central portion of the dam is called the valley section. The valley was formed by the prehistoric meanderings of Cottonwood and San Luis Creeks. The valley section can be further divided into two areas based on the underlying geology. The southern portion of the valley section (dam stations 70 to 98) bears on a wide range of materials, including layers of soft clay, sands, and gravel up to 160 feet thick. The designers of the dam were concerned that the soft clay layers could allow sliding under the weight of the embankment as it was being constructed. The design therefore included trenches excavated approximately 100 feet deep to a stronger foundation layer, one under each slope of the embankment (downstream and upstream). These were backfilled with compacted earthfill to create "shear keys" to maintain stability. The keys provide additional benefit for stability in case of earthquake. The upstream key also serves as a seepage cutoff. In addition to the foundation treatment, large, gently sloping stability berms were placed on both the upstream and the downstream faces of the dam to buttress it. Nevertheless, as in the case of the abutment sections, the clay could shear during the strongest pulses of an earthquake, resulting in settlement that significantly encroaches on the embankment's freeboard. The embankment is expected to be stable in its deformed condition at the end of the earthquake, only deforming during the strongest pulses of the earthquake.

6. At the north side of the valley section (dam stations 98-115), the foundation conditions are somewhat different. The bedrock is higher and the softer clay layers that were of concern farther south did not exist. Therefore, the downstream foundation trench and berm were not considered necessary. (The upstream cutoff and berm were constructed, however.) Near the downstream toe of the embankment, there are some loose sands that may be susceptible to "liquefaction," which is a drastic loss of strength caused by cyclic loading. The loose sands are not believed to extend upstream under the bulk of the embankment where they could cause the dam to be unstable at the end of the earthquake, but further investigation is being considered. Liquefaction only near the toe would not result in embankment instability except in the immediate area of the toe, where it could not cause a breach of the dam. However, because the remainder of the foundation material may have strength similar to the clayey materials elsewhere, deformation and settlement could be similar to that at the other portions of the dam under severe loading. Liquefaction is not an issue at the abutment sections because of the type of foundation material, or on the south side of the valley because any liquefiable materials are cut off by the stability keys.